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PROVISIONAL APPLICATION COVER SHEET

To the Commissioner of Patents and Trademarks
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This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53(b)(2).

Docket No.	13154PRO	Type a plus sign (+) inside this box →	+

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TITLE OF THE INVENTION (280 characters max)

METHOD AND DEVICES FOR MULTIPLEXING AND DE-MULTIPLEXING MULTIPLE WAVELENGTHS

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ENCLOSED APPLICATION PARTS (check all that apply)

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☒ Drawing(s) — Number of Sheets 6 — ☒ Other (specify)

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☒ A check or money order is enclosed to cover the Provisional filing fees	Provisional filing fee amount(s)	$150.00
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Respectfully submitted,

Signature: _____ Date: July 13, 1999

Typed or Printed Name: Ralph A. Dowell Registration No.: 26,868

UNITED STATES

Title: **Method And Devices For Multiplexing And De-multiplexing Multiple Wavelengths**

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FIELD OF THE INVENTION

The present invention relates to a method for separating or combining a plurality of wavelengths in a WDM fiber optic system.

BACKGROUND OF THE INVENTION

In wavelength division multiplexed (WDM) fiber optic systems, power from individual wavelengths are combined and subsequently launched into a common fiber through an optical multiplexer. After the information carrying light traverses the fiber a predetermined distance, it passes through an optical de-multiplexer where individual wavelengths are separated. Therefore, multiplexers and de-multiplexers play a key role in how WDM systems work. The most common technique for constructing such devices is to use a series of band pass filters specially staggered to separate or combine the channels so as to incur minimum loss of the optical energy in each wavelength.

One cost effective approach for making these band pass filters is to use multilayer thin film technology. Thin film filters can be designed and subsequently packaged such that light of desired wavelength passes through and all others are reflected. For practical fiber optics applications, these types of filters are typically packaged with lenses so that light from an input fiber can be brought to the filter and the corresponding transmission and reflection can subsequently be collected with two output fibers. Since thin film filters are made on large glass substrates, this approach lends itself to low cost mass production.

However, as the channel spacing decreases from 200GHz to 100GHz and beyond, it becomes increasingly more difficult to manufacture the multilayer thin film filters necessary to separate or combine the tightly spaced channels.

Thin film filters offer the most economical approach to multiplexing and de-multiplexing optical signals that are separated by 200 GHz (1.6 nm) or more. However, as the need for greater bandwidth persists, system designers are looking to use tighter channel spacing in order to satisfy this burgeoning requirement in bandwidth. In fact, systems with channel spacing of 100 GHz (0.8 nm), and 50 GHz (0.4 nm) have been designed and are being deployed in limited numbers. Manufacturing of thin film filters for these more demanding applications is inherently difficult as yields tend to fall rapidly with tighter channel spacing.

SUMMARY OF THE INVENTION

The present invention relates to a method for separating or combining a plurality of wavelengths in a WDM fiber optic system. This technique can be used in a variety of ways to more readily fabricate multiplexers and de-multiplexers using both multilayer thin film or fiber Bragg grating filters or a combination thereof. The invention can also be used, in part, to fabricate an odd/even channel separator to facilitate the use of wider bandwidth filters in applications where narrow bandwidth filters are required.

In one aspect of the invention there is provided a device for multiplexing and de-multiplexing multiple wavelengths. The device comprises a first optical

fiber including at least one odd/even select filter for splitting an optical signal passing therethrough into its odd and even components. The device includes an fiber optic branching member connected to the optical fiber, the fiber optic branching member including at least two output fibers with one of the at least two output fibers transmitting the odd components of the optical signal and the other output fiber transmitting the even components of the optical signal.

BRIEF DESCRIPTION OF THE DRAWINGS

The method for multiplexing and de-multiplexing a plurality of wavelengths forming the present invention will now be described, by example only, reference being had to the accompanying drawings, in which:

Figure 1 is a block diagram describing the function of the odd/even channel select filter;

Figure 2a is a spectrum plot of a chirped Moire grating;

Figure 2b is a spectrum plot of a modified chirped Moire grating to flatten regions of varying index and create multiple band pass filters with in the overall stop band of the filter;

Figure 3 is a detailed optical circuit which includes a circulator as the optical branching device;

Figure 4 is a detailed optical circuit with provisions for using a pair of couplers in a Mach-Zehnder interferometer arrangement in order to separate the odd and even channels without using a circulator;

Figure 5 is a detailed optical circuit which includes a coupler as the optical branching device; and

Figure 6 is a diagram of the filter assembly cascaded to allow for complete separation of part or all channels.

DETAILED DESCRIPTION OF THE INVENTION

Referring first to Figure 1, the present invention embodies the use of an odd/even channel select filter 10 together with a fiber optic branching device to reduce the overall channel density and allow the use of lower grade filters for multiplexing and de-multiplexing of optical signals. This approach can be used in a sequential manner to reduce or increase the channel density by using specially fabricated odd/even channel filters with varying bandwidth. In other words, the highest density optical signal is broken up into its odd and even components and they, in turn, are broken up to odd and even components until all channels have been separated. Alternatively, the approach may be used to reduce the channel density and then use one of many conventionally used approaches to further separate the channels.

The method forming the present invention allows for separating closely spaced optical channels by dividing the input signal into two output signals. The two outputs form odd and even signal paths such that the resulting channel density of each of the two outputs is at most half as much as the original signal. The invention then embodies the use of an odd/even channel filter together with

a fiber optic branching device to form two outputs each of which is at most half as densely populated as the original signal.

The odd/even channel select filter is comprised of a chirped Moire fiber Bragg grating whose index modulation has been selectively erased at specific locations. A chirped Moire grating consists of two superimposed linearly chirped Bragg gratings, see Figure 2a. Designing the filter appropriately creates a comb like structure with flat top band pass structures in the optical spectrum. Combining this filter with a fiber optic branching device such as a fiber optic circulator or coupler would allow separating the signals into odd and even as formed by the comb like filter. In other words, every other channel would go through such a filter while every other channel, offset by one channel, would be reflected. In this way the reflected and transmitted channels will form the odd and even parts of the initial signal.

In one preferred embodiment of the invention a specially modified chirped Moire fiber grating is used as the odd/even channel select filter. Formation of a chirped Moire fiber grating creates a wide stop band in the transmission spectrum as prescribed by the characteristics of the fiber, its index of refraction, and the chirp pattern. Chirped Moire gratings have spike like features in their overall stop band. These features are repeated periodically which by design creates a simple and elegant fix on the wavelength grid. Washing out certain regions of the index modulation, or stated in another way, erasing the grating in specific locations, in the chirped grating pattern simply creates the desirable flat

top openings in the spectrum. The use of this grating together with a three port fiber optic circulator 20 shown in Figure 3 forms a convenient way for separating the input spectrum 22 into two output signals with one comprising the odd components 24 and the other comprising the even components 26 of the original signal 22.

It may also be preferred to use a directional coupler for separating the odd and even channels such as illustrated in Figures 5A and 5B. In one embodiment of this arrangement, shown generally at 60 in Figure 5A, a directional coupler 64 is used to initially divide the signal and then an odd/even channel select filter 68 is used on port 2 (output 2) to pass the odd or even wavelengths while the other port 70 (labeled output 1), is used to pass the interleaved signals.

Alternatively, referring to Figure 5B, the second through arm 70 of the coupler 64 can be used where each of the two output arms of the coupler are outfitted with single or multiple channel select filters 68 and 72 offset in each arm to allow the passage of even channels from one arm of the coupler and odd channels from the other. This approach has the benefit that the power in odd and even channels as a result of the separation remains relatively the same. However, it requires two filters each placed in one arm of the filter as opposed to the arrangement shown in Figure 5A.

Another embodiment of the device constructed according to the present invention is shown in Figure 4 and comprises a fiber optic Mach-Zehnder interferometer 40 comprises two identically fabricated filters 42 and 44 placed

in the two arms thereof to separate the odd and even channels. The couplers 46 and 48 are used to combine the portions of the light that interfere with each other as a result of the interferometer arrangement. This then allows the constructive and destructive parts of the interference to be separated with minimal loss to the optical energy.

Figure 6 shows an example of using the odd/even channel select filters by using any of the arrangements described hereinafter to separate all the wavelengths of an incoming signal. In these embodiments shown in Figure 6 the box-like elements represent filters used for the separation of the odd and even channels.

In one such arrangement, a widely chirped fiber grating with regions of constant index or a sampled fiber grating which consists of periodic regions of varying index and constant index can be used as the odd/even channel select filter. In the former, a widely chirped, spectrally broad, grating is holographically written into the core of an optical fiber which is subsequently exposed to dc UV radiation at the appropriate wavelength which creates regions of constant index in pre-selected locations. This effectively creates a chirped sampled grating whose spectrum will also have a comb like structure. The main difference between a chirped sampled grating and a chirped Moire grating is the absence of the spike like features in the spectrum for Moire gratings. These features can be used to provide an absolute fix in the wavelength spectrum. In addition, due to the nature of the grating formation, it may be beneficial to use the chirped

Moire grating for obtaining better insertion loss as well as improved spectral characteristics on a per channel basis.

In a variation of this embodiment, several co-located gratings are fabricated in the fiber which forms the comb like filter as described in the previous two embodiments. Co-located gratings are fiber gratings fabricated in the same physical location in the optical fiber. The advantage to making co-located gratings as opposed to individual gratings which are subsequently spliced together is the ability to package them in an athermal arrangement with significant space savings. An athermal grating is a packaged grating in a mechanical or thermal arrangement such that the characteristic thermal sensitivity of the grating's center wavelength in neutralized as described in US Patent No. 5,042,898. This arrangement allow for a great deal of flexibility as any combination of filter shape and structure is possible through fabrication of these individual gratings which are co-located.

The foregoing description of the preferred embodiments of the invention has been presented to illustrate the principles of the invention and not to limit the invention to the particular embodiment illustrated. It is intended that the scope of the invention be defined by all of the embodiments encompassed within the following claims and their equivalents.

THEREFORE WHAT IS CLAIMED IS:

1. A device for multiplexing and de-multiplexing multiple wavelengths, comprising:

a first optical fiber, the first optical fiber including at least one odd/even select filter for splitting an optical signal passing therethrough into its odd and even components; and

a fiber optic branching member connected to said optical fiber, the fiber optic branching member including at least two output fibers with one of said at least two output fibers transmitting the odd components of the optical signal and the other output fiber transmitting the even components of the optical signal.

2. The device according to claim 1 wherein the channel select filter is a chirped Moire fiber Bragg grating whose index modulation has been selectively erased at preselected locations.

3. The device according to claim 2 wherein the fiber optic branching member is a fiber optic circulator or coupler.

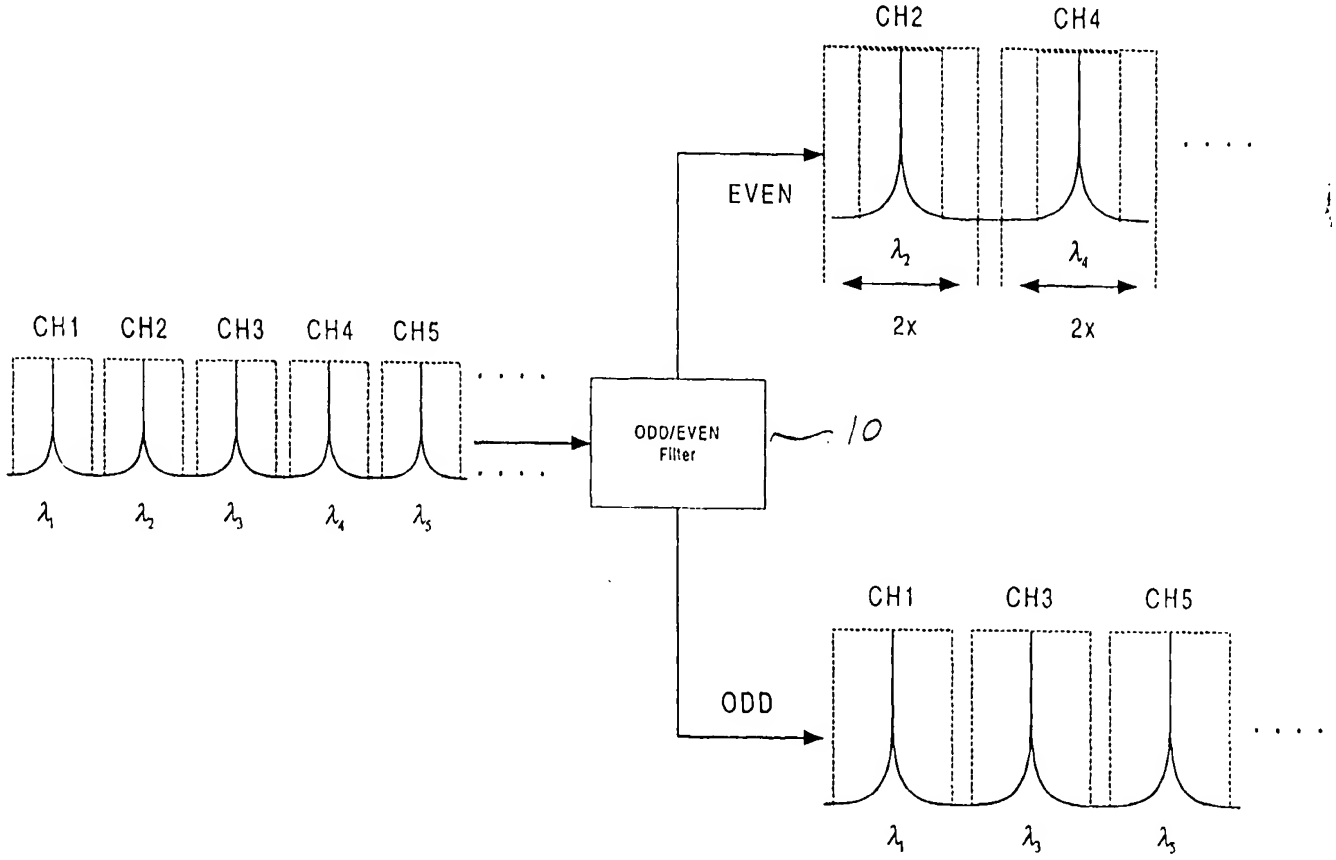
4. The device according to claim 1 wherein the channel select filter is a chirped sampled grating.

5. The device according to claim 1 wherein said at least one odd/even select filter is a plurality of co-located gratings.

6. The device according to claim 1 wherein the fiber optic branching member is a thin film multilayer dielectric filter including input and output optical fibers so as to direct light in a predetermined manner.

ABSTRACT

The present invention provides a method for separating or combining a plurality of wavelengths in a WDM fiber optic system. This technique can be used in a variety of ways to more readily fabricate multiplexers and de-multiplexers using both multilayer thin film or fiber Bragg grating filters or a combination thereof. The invention can also be used, in part, to fabricate an odd/even channel separator to facilitate the use of wider bandwidth filters in applications where narrow bandwidth filters are required.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CH4
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CH3
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λ_1
λ_2
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ODD
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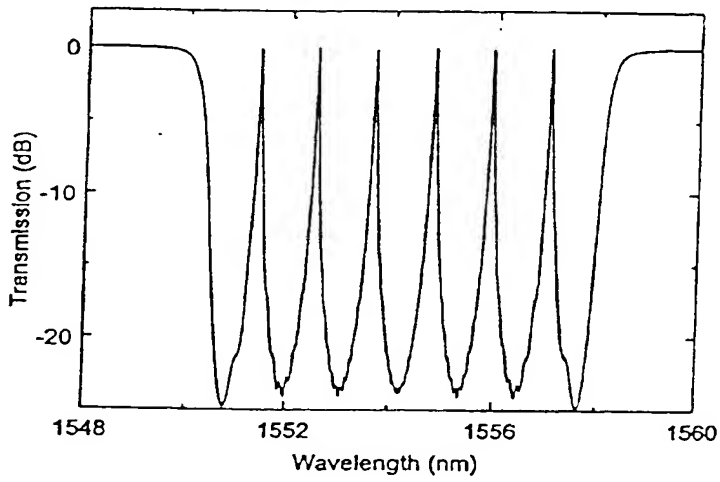
FIGURE 1

FIG. 2 (a)



b

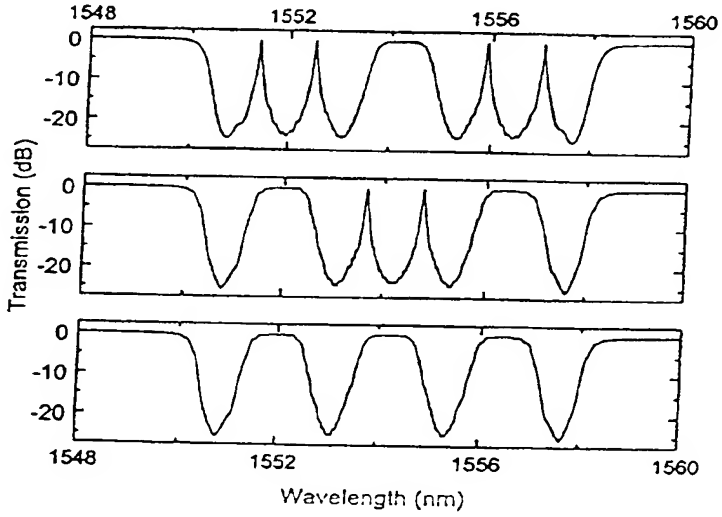


FIG. 2b

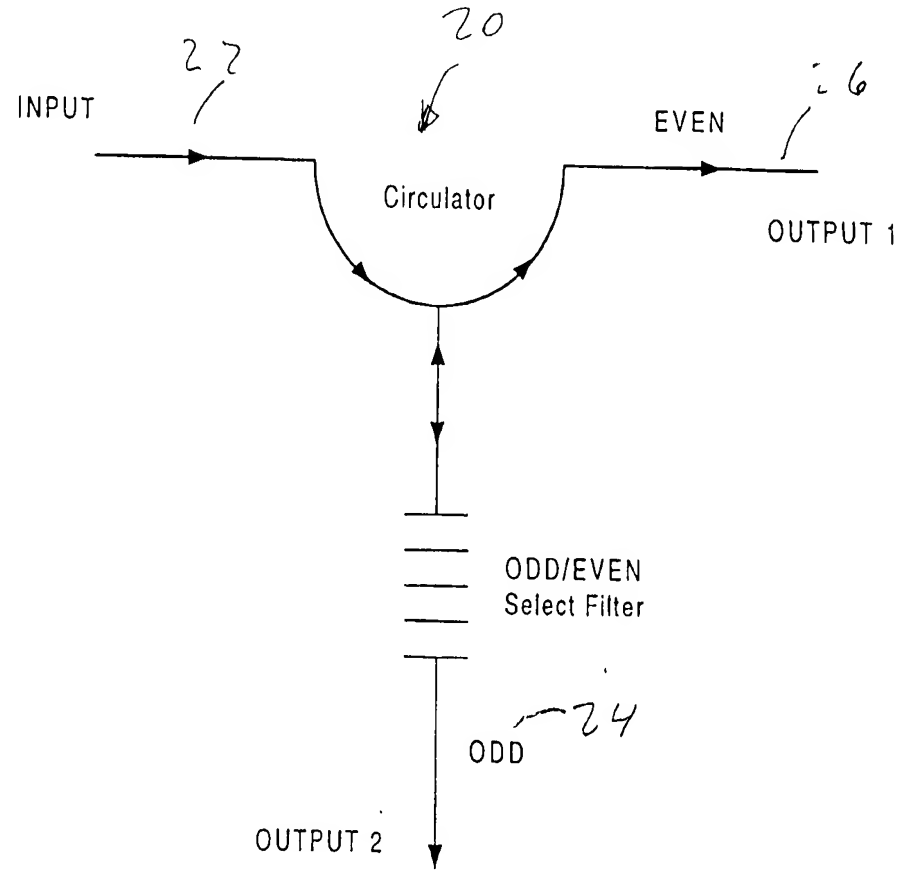

20
22
INPUT
26
EVEN
Circulator
OUTPUT 1
ODD/EVEN
Select Filter
24
ODD
OUTPUT 2

FIG. 3

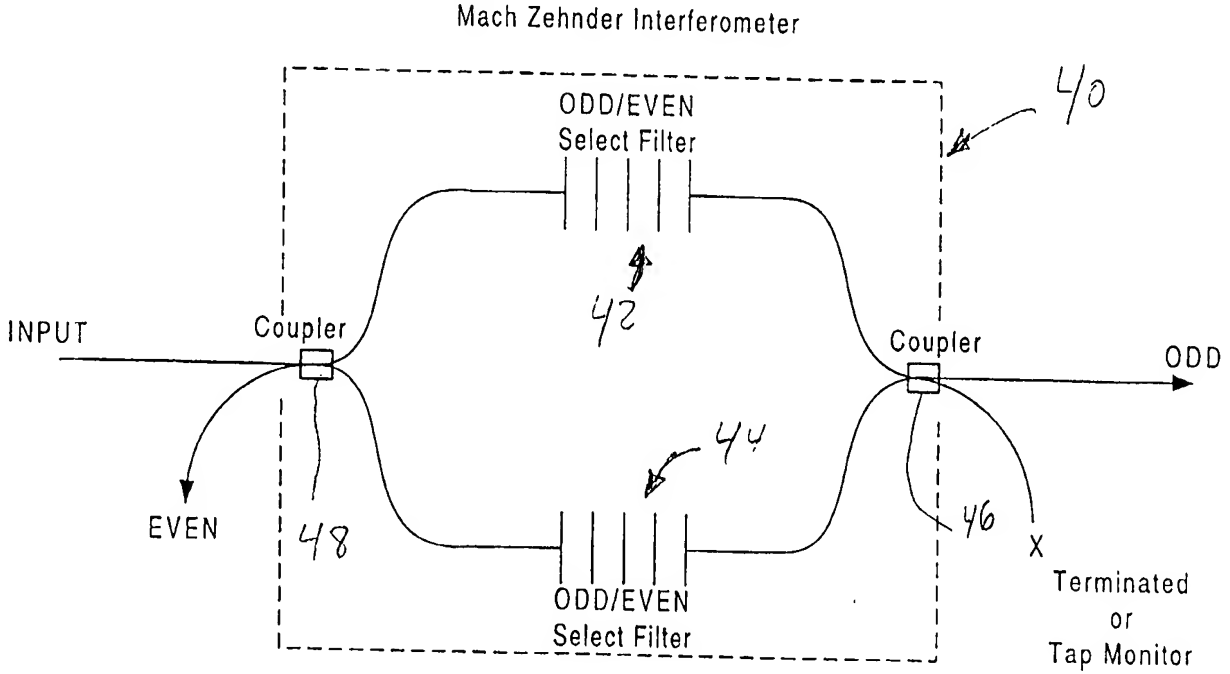


FIG. 4

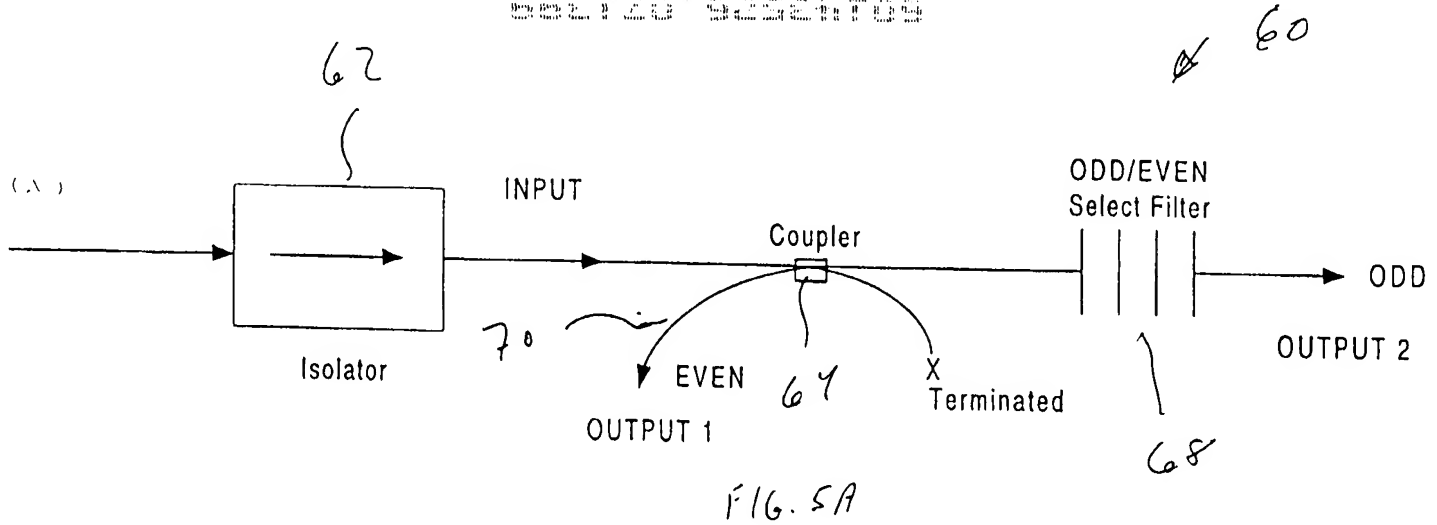


FIG. 5A

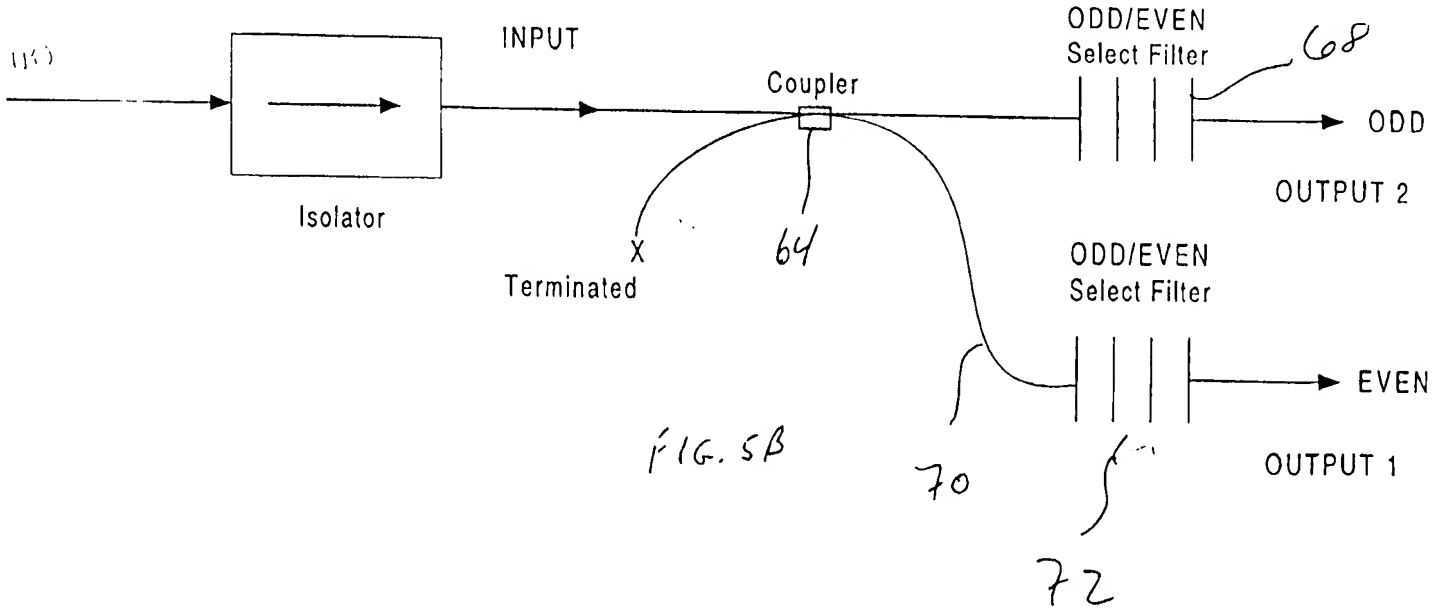
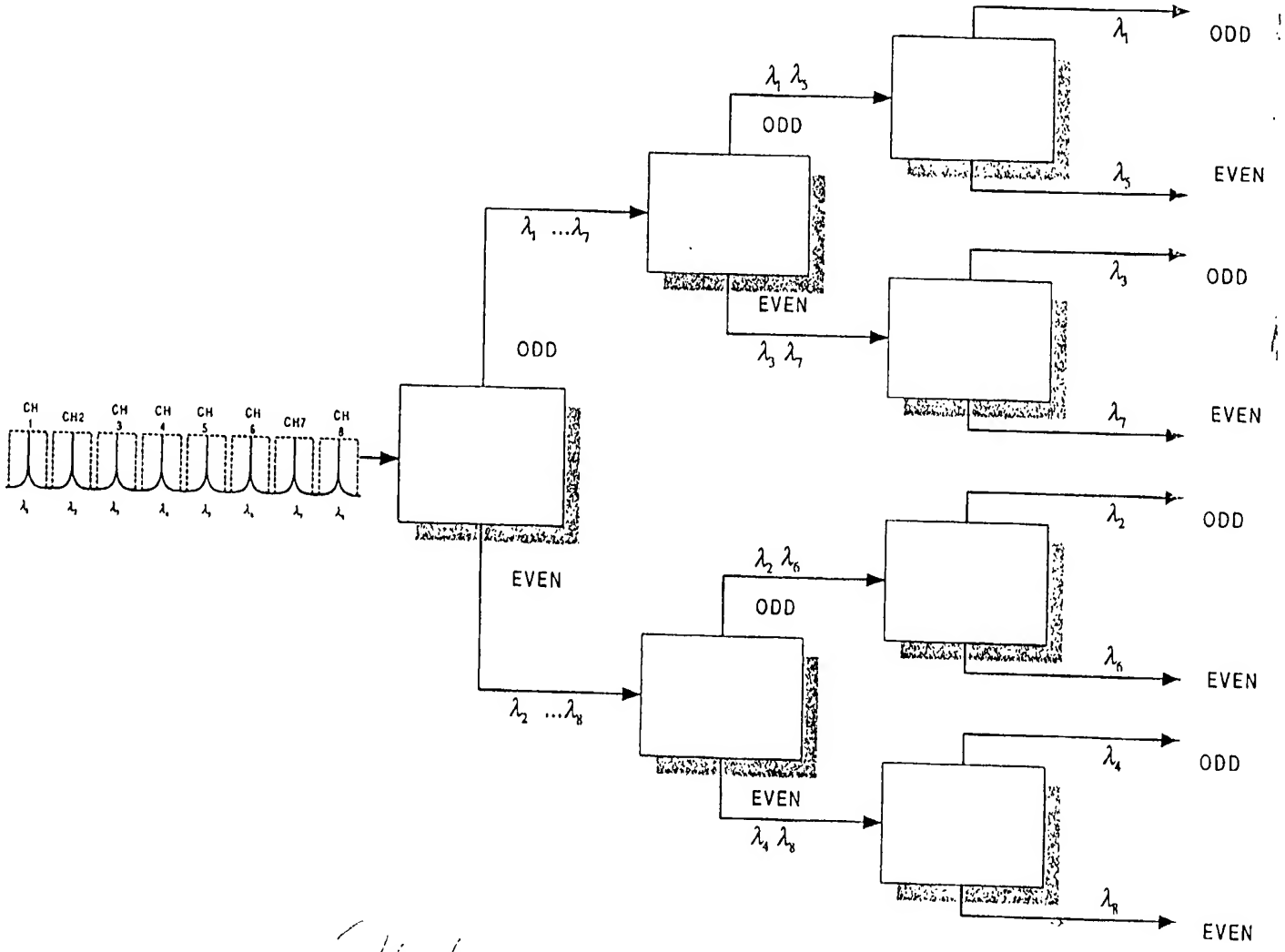


FIG. 5B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CH2
CH 3
CH 4
CH 5
CH 6
CH7
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Fig. 6